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Measurement of technical efficiency and its determinants in sampea-11 variety of cowpea production in Niger State, Nigeria

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Abstract

The study examined the technical efficiency of SAMPEA-11 variety of cowpea production in Niger State, Nigeria. Multi-stage sampling technique was employed to sample 152 SAMPEA-11 farmers from which input-output data were collected based on 2013 cropping season. Descriptive statistics, stochastic frontier production model were employed for data analysis. The descriptive analysis revealed that 88% of the respondents were literate with mean age of 39 years. The mean household sizes, years of farming experience and years in cooperative society of the respondents was 10 people, 11.7 years and 6 years respectively. Results from the stochastic frontier production model indicated that three variables, namely; seed, herbicide and insecticide were positive significant determinants of SAMPEA-11 output at 1% probability level each. It was also revealed that the socio-economic variables; age and farming experience were significant determinants of technical efficiency at 10% and 1% level of probability respectively. The mean technical efficiency indices of the respondents ranged was 76% indicating that farmers were operating below the efficiency frontier. The study concluded that quantity of seed used, herbicide and pesticide were significantly influencing the output of SAMPEA-11 in the study area. Also, the respondents were not fully efficient in their resource allocation and therefore there is allowance for improvement through intensive collaboration among institutions, governmental extension departments and farmer associations in order to implement farming experiments and best management practices such as optimizing input application.

Key words: SAMPEA-11 Production, Technical Efficiency and Determinants.

INTRODUCTION

Cowpea (*Vigna Unguiculata L. Walp*) plays a critical role in the lives of millions of people in Africa and other parts of the developing world, where it is a major source of dietary protein that nutritionally complements staple low-protein cereal and tuber crops, and is a valuable and dependable commodity that produces income for farmers and traders (Singh, 2002; Langyintuo *et al.,* 2003). It sustains the people who live on the very edge of existence and it thrives in hot, dry conditions. Drought tolerance, short growing period and its multi-purpose use make cowpea a very attractive alternative for farmers who cultivate in marginal, drought-prone areas with low rainfall and less developed irrigation systems, where infrastructure, food security and malnutrition are major challenges (Hallensleben *et al*., 2009). Cowpea provides income and employment opportunities for most people in the rural communities, particularly women who are entirely responsible for its processing and marketing. It provides them additional earning opportunity to contribute to the household food security.

Early maturing cowpea varieties can provide the first food from the current harvest sooner than any other crop (in as few as 55 days after planting), thereby shortening the “hungry period” that often occurs just prior to harvest of the current season’s crop in farming communities in the developing world. SAMPEA-11 was among the two improved cowpea varieties that was developed and released in 2010 by scientists working at the International Institute of Tropical Agriculture (IITA), Ibadan, in collaboration with the Institute for Agricultural Research of the Ahmadu Bello University, Zaria; the University of Maiduguri, Borno; and the Agricultural Development Programs of Borno, Kaduna, Kano, and Katsina States. SAMPEA-11 is a dual-purpose cowpea variety with large white seeds and a rough seed coat. It has combined resistance to major diseases including septoria leaf spot, scab, and bacterial blight, as well as to nematodes, and tolerance to Nigeria’s strain of *Striga gesnerioides* (a parasitic weed that severely lowers yield) (IITA, 2010). It has proven to be superior over the current improved lines being cultivated with a yield advantage of at least 80% over the local varieties (Kamara, 2010).

It is a major food crop which is widely grown in Niger state, however, with increasing population over the years, the demand for the crop had gone up but the production has not been increased significantly (Agwu, 2001). Despite its importance and the introduction of improved varieties such as SAMPEA-11 to curb some of the challenges that hinder its productivity; there is still the insufficiency of the crop. This study is therefore to evaluate the technical efficiency of SAMPEA-11 production in Niger State, Nigeria and also identifies the determinants of efficiency in the production process.

Conceptual Framework

In the Stochastic frontier analysis (SFA), the error term is assumed to have two components parts V and U. The V covers the random effects (random errors on the production and they are outside the control of the decision unit) while the U measures the technical inefficiency effects, which are behavioural factors that come under the control of the decision unit. They are controllable errors if efficient management is put in place. The stochastic frontier analysis is generally preferred for agricultural research for the following reasons: the inherent variability of agricultural production due to inter play of weather, soil, pests, diseases and environmental factors and many firms are small family owned enterprise where keeping of accurate records is not always a priority hence available data on production are subject to measurement errors.

The application of the stochastic frontier model for efficiency analysis include: Aigner, *et al.,* (1977) in which the model was applied to U.S. agricultural data. Battese and Corra (1977) applied the technique to the pastoral zone of eastern Australia. More recently, empirical analysis has been reported by Bravo-Ureta and Pinheiro (1993).

The stochastic frontier production function model is specified as Y= f(X_i,β)+e, where Y is output in a specified unit, X denotes the actual input vector, β is the vector of production function parameters and e is the error term that is decomposed into two components, V and U. the V is a normal random variable that is independently and identically distributed with zero mean and constant variance σ^2. It is introduced to capture the white noise in the production, which are due to factors that are not within the influence of the producers. It is independent of U the U is a non negative one sided truncation at zero with the normal distribution (Tadesse and Krishnamoorthy, 1977), it measures the technical inefficiency relative to the frontier production function, which is attributed to controllable factors (technical inefficiency). It is half normal, identically and independently distributed with zero mean and constant variance. The variance of the random errors (σ_v^2) and that of the technical inefficiency effects (σ_u^2) and overall model variance (σ^2) are related thus: $\sigma^2 = \sigma_v^2 + \sigma_u^2$, and the ratio $\gamma = \sigma_u^2/\sigma_v^2$ is called Gamma. Gamma measures the total variation of output from the frontier, which can be attributed to technical inefficiency.

The technical efficiency of an individual firm is defined in terms of the observed output Yi to the corresponding frontier output Y_i^*. The Y_i^* is maximum output achievable given the existing technology and assuming 100% efficiency. It is denoted as: Y_i^* = f(Xij,β) +V that is TE= Yi / Y_i^*. Also the TE can be estimated by using the expectation of Ui conditioned on the random variable (V-U) as shown by Battese and Coelli 1988. That is TE = f(Xi,β) + V-U / f(Xi,β) +V and that 0≤TE≤1.

MATERIALS AND METHODS

Study Area

This study was conducted in Niger State. The state is located in the middle belt of Nigeria at latitudes 8° 20´ and 11° 30´ N and longitudes 3° 30´ and 7° 20´ E of the prime meridian with land area of 76,470 km^2 about 10 percent of Nigeria‘s total land area, out of which about 85% is arable (Niger State Bureau of Statistics, 2011). This makes the state the largest in the country with a population of 3,950,249 (National Population Commission, 2006). Using 3.4 growth rate as allowed by National Population Commission, Niger state stands at 4,991,927 (2013 projection). The state is bounded in the North by Zamfara State, in the North-West by Kebbi State, in the South by Kogi State, in the South-West by Kwara State and in the North-East and South-East by Kaduna state and the Federal Capital Territory respectively. Furthermore, the State shares a common international boundary with the republic of Benin at Babanna in Borgu Local Government Area of the State (Niger State Bureau of Statistics, 2011).

The state experiences two distinct seasons: the dry and wet seasons. The annual rainfall varies from about 1,600mm in the south to 1,200mm in the north. The duration of the rainy season ranges from 150 to 210 days or more from the north to the south. Mean maximum temperature remains high throughout the year, hovering at about 32°C, particularly in March and June. The lowest minimum temperatures occur usually between December and January when most parts of the state come under the influence of the tropical continental air mass which blows from the North. Dry season in Niger State commences in October. The vegetation consists mainly of short grasses, shrubs and scattered trees.

Sampling Techniques

The data mainly from primary sources were collected using structured questionnaire from three Local Government Areas (LGAs) which were purposively selected because of prevalence of the crop in the area using multistage sampling technique. The LGAs include Bosso, Kontagora and Mokwa LGAs. In the second stage, two villages were randomly selected in each of the three selected L.G.As. Finally (third stage), from the sampling frame of 1010 farmers, 152 farmers were randomly selected from the six villages representing 15% of the sampling frame.

Information collected include labour input, capital inputs, output, prices and farmers' socio-economic characteristics such as age, farming experience, level of education, household size, farm size, years spent in cooperative societies and extension contact. The analysis of data was done by estimation of stochastic frontier production function model.

Method of Data Analysis

Both descriptive and Stochastic Frontier Production function was employed for this study. Descriptive statistics were used in describing the socio-economic attributes of the farmers.

Stochastic Production Frontier Model Specification

The stochastic frontier function used by Onu *et al.* (2000) and Parikh and Shah (1995) as derived from the error model of Aigner, Lovell and Schmidt (1977) was employed to elicit the determinants of technical efficiency of the farmers in SAMPEA-11 production in the study area. The maximum likelihood estimate of the parameters of the stochastic production frontier model was obtained using the program FRONTIER VERSION 4.1c (Coelli, 1996). The Cobb-Douglas production function was fitted to the frontier model of SAMPEA-12 production. The stochastic production function is written as:

$Y_i = f(X,: \beta) + e_i$

$e_i = V_i - U_i$

Where:

Y_i = Yield of the farm

X_i = Vector of inputs used by the farm

β = A vector of the parameters to be estimated

V_i = Random error outside farmer's control

U_i = Technical inefficiency effects

The empirical stochastic frontier production model that was employed is specified as follows:

$\ln Y_j = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + V_i - U_i$

Where;

Subscripts ij refers to the jth observation of ith farmer,

In =Logarithm to base e,

Y = Yield of cowpea (kg/ha)

β_0 = Constant

β_1 - β_5 = Parameters to be estimated

X_1 = Quantity of seed (kg/ha)

X_2 = Quantity of herbicide (liters/ha)

X_3 = Quantity of insecticide (liters/ha)

X_4 = Fertilizer (Kg/ha)

X_5 = Labour (man-days/ha)

V_i = Random noise (white noise)

U_i = Are efficiency effect which are non negative with half normal distribution.

It is assumed that inefficiency effects are independently distributed and Uij arises by truncation (at zero) of the normal distribution with mean Uij and variance δU^2 where Uij is specified as;

$U_i = \delta_0 + \delta_1 \ln Z_{1i} + \delta_2 \ln Z_{2i} + \delta_3 \ln Z_{3i} + \delta_4 \ln Z_{4i} + \delta_5 \ln Z_{5i} + \delta_6 \ln Z_{6i}$

Where;

Ui = Technical inefficiency of the ith farmer

δ_0 = Constant

$\delta_1 - \delta_6$ = Parameters to be estimated

Z_1 = Farmer's age (years)

Z_2 = Household size of ith farmer (number)

Z_3 = Years of formal education of the ith farmer (years)

Z_4 = Years of farming experience of the ith farmer in crop production (years)

Z_5 = Years spent in cooperative society (years)

Z_6 = Number of contacts with extension agents (measured as number of contacts in a year).

RESULTS AND DISCUSSION

The socioeconomic characteristics of SAMPEA-11 farmers were considered in this study because of their perceived effects on the agricultural activities as shown in

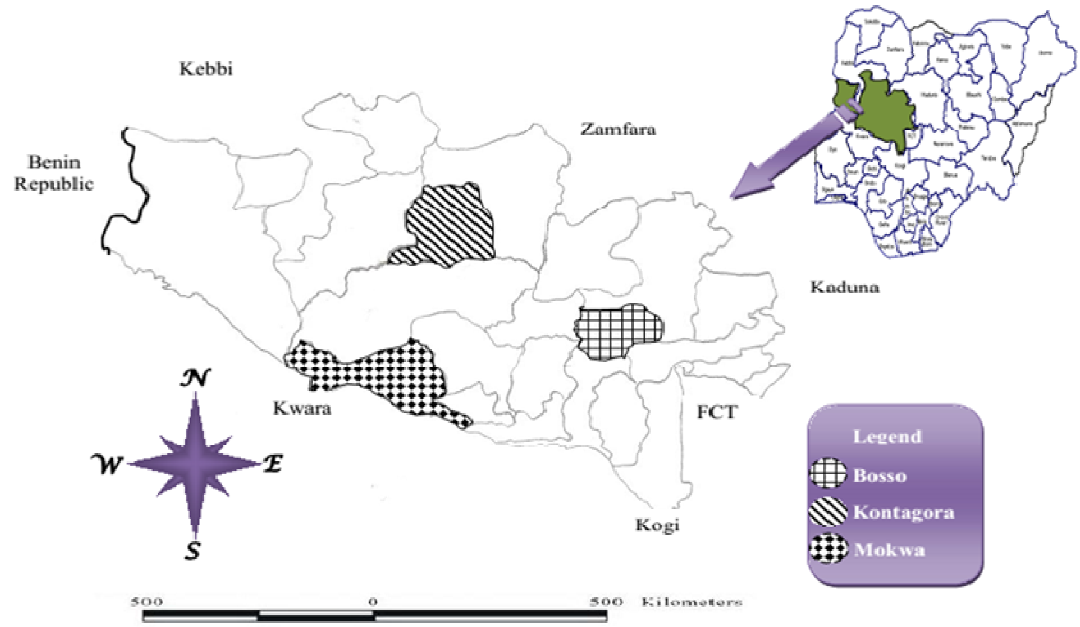

Figure 1: Map of Nigeria showing the study area

Table 2. The mean age of the farmers was 39 years which implies that the farmers are still in their active age that can make positive contribution to agricultural production. The older the farmer, the more experienced he/she is expected to be, which aids in decision making. Most respondents (88%) had one level of educational attainment or the other, implying that they are literate. Their educational status is enough to provide them with the ability to read and write, handle and interpret messages relating to their farm operation in the instruction manuals on input and machinery uses, and also enable them to appreciate extension services. Sullumbe, 2004 opined that Education is a major determinant of the Nation's economy. He further argues that the level of formal education attained by an individual goes a long way in shaping his personality, attitude to life and adoption of new and improved practice. The mean household size of the respondents was 10 people per household. Although large family size can sometimes be an asset to the farmers in terms of available work force/labour, often time a farmer is faced with the challenges of providing social and welfare facilities such as feeding, education, sheltering, health care and other living expenses for such a large number of dependants. These expenses account for low saving at the end of every harvest season aside the fact that most farm produce are consumed by the large household members. The mean years of farming experience of the respondents was 11.7 years which shows that the managerial ability of the farmers can be inferred to be reasonably good. The mean area of land devoted to SAMPEA-11 production was 2.2 hectares which indicates that the respondents were small-scale farmers. Factors such as long distances to farm site, high cost of land, high cost of labour and low income level could be responsible for this phenomenon. It was also revealed that few (39%) of the respondents were members of cooperative societies and had spent various years with a mean of 6 years in cooperative organization. Naturally, being members of associations afford farmers to benefit from financial institutions and/or lending agency since such requirement is the determinant factor. Farmers who belong to cooperatives are better informed on resources use and farm planning which enables them to utilize resources more efficiently. Contact with extension agents in the production year of most (92%) of the respondents ranged between 1 and 3 contacts. Through extension visits, farmers become better informed about farm management planning and new technologies, hence improving their efficiency in production. Mbanasor and Kalu (2008) in their study found that the number of extension visits had a significant positive relationship with economic efficiency of commercial vegetable farmers in Akwa Ibom State, Nigeria

The Maximum Likelihood Estimate (MLE) of the Cobb-Douglass stochastic frontier model with half-normal distribution assumption made on the efficiency error term is presented in Table 3. Sigma-squared (σ^2) estimated as 0.76 and significantly different from zero at 1% level of probability indicates a goodness of fit and correctness of the distribution form assumed for the composite error term. The gamma estimate of 0.26 was significantly

Table 2: Socio-economic characteristics of the respondents

Characteristics	Frequency	Percentage
Age of the farmer (Years)		
20 – 32	54	35.53
33 – 45	60	39.47
46 – 58	30	19.74
59 and above	8	5.26
Mean = 39		
Education of household head		
No formal education	19	12.50
Primary	46	30.26
Secondary	39	25.66
Tertiary	48	31.58
Household size		
1 – 7	24	15.79
8 – 14	86	56.58
15 and above	42	27.63
Mean = 10		
Farming Experience (Years)		
1 – 9	63	41.45
10 – 18	79	51.97
19 and above	10	6.58
Mean = 11.7		
Farm Size (Ha)		
0.1 – 1.0	28	18.42
1.1 – 2.0	100	65.79
2.1 and above	24	15.79
Mean = 2.2		
Cooperative society (years)		
0	93	61.18
1 – 5	30	19.74
6 – 11	12	7.89
12 and above	17	11.18
Mean = 6		
Extension Contact		
1 – 3	139	91.45
4 – 7	11	7.24
8 and above	2	1.31
Total	**152**	**100.00**

Source: Computed from field survey data, 2014

different from zero at 1% level of probability shows the amount of 26% variation in output resulting from the technical inefficiencies of the farmers. Typical of the Cobb–Douglas production function, the estimated coefficients for the specified function can be explained as the elasticities of output of the explanatory variables. The estimate of the parameters of the stochastic production frontier indicated that the elasticity of output with respect to seed (X_1) was positive and statistically significant at 1% level of probability. An increase of 1% in seed will result to an increase in output by 0.284%; the production elasticity of herbicide (X_2) was positive and statistically significant at 1% level of probability implying that 1% increase of herbicide will result in an increase in output by 0.205%; also the production elasticity of insecticide (X_3) was positive and it was statistically significant at 1%. This implies that an increase of 1% in insecticide will result in an increase in output by 0.185%.

Table 3: Maximum Likelihood Estimates of Stochastic Frontier Production Function of SAMPEA-11 Production in Niger State, Nigeria

Variables	Coefficients	Standard Error	T-ratio
Constant	4.5763	0.3102	14.7535
Seed (X_1)	0.2844***	0.0718	3.9589
Herbicide (X_2)	0.2054***	0.0653	3.1471
Insecticide (X_3)	0.1850***	0.0733	2.5232
Fertilizer (X_4)	0.0163	0.0581	0.2806
Labour (X_5)	0.0747	0.0810	0.9217
Variance parameters			
Sigma-squared (σ^2)	0.7604***	0.0983	7.7355
Gamma (γ)	0.2642***	0.0238	11.1008
log likelihood	14.6646		
Number of observations (n) = 152			

Source: Computed from field survey data, 2014.
***P<0.01 ** P<0.05 *P<0.10

Table 4: Technical Efficiency Distribution of SAMPEA-11 Farmers in Niger State

Technical Efficiency Level	Frequency	Percentage
0.10–0.24	6	3.95
0.25–0.49	25	16.45
0.50–0.74	23	15.13
0.75–1.00	98	64.47
Total	152	100.00
Minimum	0.16	
Maximum	0.98	
Mean	0.76	

Source: Computed from field survey data, 2014

The frequency distribution of technical efficiency levels for SAMPEA-11 farmers in the study area is presented in Table 4. The mean technical efficiency was 0.76, which suggested that on average for SAMPEA-11 farms, the observed output was 24% less than the optimum output. This implies that SAMPEA-11 farmers on the average were technically efficient (0.76) and were 24% less from the maximum possible level due to technical inefficiency on which they can improve by employing the best practices and existing technologies. The results indicate that technical efficiency (TE) indices range from 16% to 98% for farms in the sample, with an average of 76%. This means that if the average farmer in the sample was to achieve the TE level of its most efficient counterpart, then the average farmer could realize a 22% cost savings (i.e., 1 - [76/98]). A similar calculation for the most technically inefficient farmer reveals cost savings of 84% (i.e., 1 – [16/98]). In line with previous efficiency studies, Ojo *et al.*'s (2009) study of onion farmers in Sokoto revealed a TE of 0.95, while Usman *et al*.'s 2010 study of sesame farmers reported a much lower mean TE of 0.57.

The existence of technical inefficiency paves way to find out the sources of inefficiencies among SAMPEA-11 farmers in the study area. Socio-economic variables were considered and estimated in the model and the results are presented in Table 4. The hypothesis that there are no inefficiencies was rejected at the 1% level of significance. Positive or negative signs on the coefficients indicate that increase in the variable increases or decreases inefficiency respectively. The signs and coefficients in the inefficiency model are interpreted in the opposite way, such that a negative sign means the variable increases efficiency and vice versa. The result of the inefficiency model shows that the coefficient estimates for education, household size and membership of cooperative society were not statistically significant. This implies that these characteristics did not contribute to technical efficiency in SAMPEA-11 production.

Table 5: Determinants of Technical Inefficiency

Variable	Coefficient	Standard Error	T-ratio
Constant	0.2650	0.1941	1.3648
Age (Z_1)	-0.0079*	0.0041	-1.9103
Education (Z_2)	-0.0067	0.0093	-0.7190
Household Size (Z_3)	0.0134	0.0141	0.9537
Farming experience (Z_4)	-0.0073***	0.0028	-2.6071
Years in cooperative society (Z_5)	0.0340	0.0855	0.3976
Extension contact (Z_6)	-0.0623	0.0404	-1.5429

Source: Computed from field survey data, 2014.
***P<0.01 ** P<0.05 *P<0.10

The estimated coefficient for age (Z_1) was negative and statistically significant at 10% level of probability. This implies that farmers who are older tend to be more efficient in SAMPEA-11 production. This is in line with Msuya *et al.* (2008) and Amos (2007) who found that age increases technical efficiency. It is believed that experience increases with age and resource endowment, hence giving an increase in efficiency. On the contrary, Ajibefun and Abdulkari (2004), Ajibefun (2006), Ogundele (2003), and Otitoju and Arene (2010) have stated that age of farming household heads have an inverse relationship with productivity of farmers in Nigeria. They argued that this was understandable since it was expected that as a farming household head becomes older, the farmer's productivity would decline. The coefficient estimate for farming experience (Z_4) was negative and statistically significant at 1% level which implies that farmers with more farming experience tend to be more efficient in SAMPEA-11 production. This is in line with the findings of Yusuf (2007) who posits that, experience is the first determinant of profitability because it can inform farmers to adjust to changing economic conditions and adopt the most efficient cultural practice. Years of farming experience increase as the age of the farmer increases. Studies conducted in the humid forest and moist savannah agro-ecological zones of Nigeria showed that productivity was positively associated with more experience in farming (Ajibefun and Abdulkadri, 2004; Ajibefun, 2006; Idjesa, 2007; Ogunniyi and Ojedokun, 2012). Gul *et al.* (2009) and Ogisi, Chukwuji, Christopher and Daniel (2012) also found that farming experience has a positive effect on technical efficiency among cotton farmers in Cukurova region, Turkey and rice farmers in Nigeria, respectively.

The estimated coefficient of extension contact (Z_6) was negative and was statistically significant at 10% level of probability, implying that farmers with more extension contacts tend to be more efficient in SAMPEA-11 production. This is in consonance with the findings of Akinbode *et al.* (2011), Kamruzzaman and Hedayetul (2008); Ogisi *et al.* (2012) that, increase in extension contact has a positive influence on technical efficiency. Extension services, if properly implemented, should increase the efficiency of farmers, since farmers would obtain the knowledge of using innovations that will improve their productivity.

CONCLUSION

The study revealed that technical efficiency in SAMPEA-11 production in Niger State ranged from 16% to 98% with a mean of 76% for farms in the sample. This implies that there are considerable opportunities to increase productivity and income through more efficient utilization of productive resources. Relevant factors related to technical efficiency were seed, herbicide, pesticide, age and farming experience.

RECOMMENDATION

The results from the study revealed that seed, herbicide and pesticide are positive significant factors influencing SAMPEA-11 production in Niger State. Farmers in the study area need to form viable cooperative societies to enable them access improved inputs especially appropriate inorganic fertilizers, pesticides and institutional credit at reasonable costs. Also, the State Government should take advantage of IFAD Adaption for Smallholder Agriculture Programme (ASAP), an initiative that will assist farmers in achieving sustainable cowpea production, amongst other benefits. ASAP is to be implemented under the IFAD Assisted Community Based Agriculture and Rural Development Programme-II proposed for implementation by 2015 in Nigeria; the State Government make provisions for safeguard against negative environmental effect that may likely arise from the use of technologies promoted while managing the resultant social adjustment process.

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